

TITLE OF THE INVENTION

SEMICONDUCTOR DEVICE HAVING TRENCH CAPACITOR FORMED IN  
SOI SUBSTRATE, AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

5           This application is based upon and claims the  
benefit of priority from the prior Japanese Patent  
Application No. 2001-193323, filed June 26, 2001, the  
entire contents of which are incorporated herein by  
reference.

10                           BACKGROUND OF THE INVENTION

1.   Field of the Invention

          The present invention relates generally to  
a semiconductor device and a method of manufacturing  
the same, and more specifically to an SOC (System On  
15   Chip) technique for combining a DRAM device having  
a memory cell with a trench capacitor structure and  
a logic device on an SOI (Silicon On Insulator)  
substrate.

2.   Description of the Related Art

20           With the developments in information communication  
technologies in recent years, in a semiconductor device  
which performs, e.g., image processing, the SOC  
technique for combining a DRAM device and a logic  
device in a single chip is desired in order to achieve  
25   high-speed data transfer between a memory and a logic  
circuit. It is one of the weighty SOC techniques to  
apply the SOI technique, which can realize a high-speed

and low-power-consumption logic device, to the DRAM device.

FIG. 1 is a cross-sectional view schematically showing a memory cell formed when a DRAM having  
5 a memory cell with a trench capacitor structure is manufactured by an SOI technique. Specifically, FIG. 1 illustrates a conventional semiconductor device and a method of manufacturing the same. The memory cell is provided in an SOI substrate 11. The SOI substrate 11  
10 includes a BOX (Buried Oxide) film 11-3 formed between a semiconductor region (substrate) 11-1 at a plate side and a semiconductor region (P-well region) 11-2 at an element region side. Specifically, the SOI substrate 11 is provided with a trench (deep trench) 12  
15 with a depth to reach the substrate 11-1, extending from the P-well region 11-2 and passing through the BOX film 11-3. A capacitor (trench capacitor) 13 is formed within the trench 12. A cell transistor 14 for selecting the capacitor 13 is formed on the P-well  
20 region 11-2 in a state where one of source and drain regions 15, 16 of the transistor 14 is connected to one electrode of the cell capacitor 13.

However, with the above structure, since the P-well region 11-2 and the substrate 11-1 are  
25 electrically insulated by the BOX film 11-3, the P-well region 11-2 is in a floating state. This causes a problem that the channel potential of the cell

transistor 14 cannot be controlled, and the operation becomes unstable.

#### BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention,  
5 there is provided a semiconductor device comprising:  
an SOI substrate including a first semiconductor  
region, a buried insulating film formed on the first  
semiconductor region, and a second semiconductor region  
formed on the buried insulating film; a trench with  
10 a depth to reach the first semiconductor region,  
extending from a surface of the second semiconductor  
region in the SOI substrate and passing through the  
buried insulating film; a trench capacitor formed  
within the trench; and a conductive layer formed in  
15 a region between a sidewall portion of the trench and  
the buried insulating film, the conductive layer  
electrically connecting the first semiconductor region  
and the second semiconductor region.

According to another aspect of the present  
20 invention, there is provided a method of manufacturing  
a semiconductor device, comprising: forming a trench in  
an SOI substrate, the trench extending from a major  
surface of the SOI substrate and passing through  
a buried insulating film; forming a first insulating  
25 film in the trench, the first insulating film with  
a depth to reach an upper surface of the buried  
insulating film; forming a second insulating film in

a sidewall portion of the trench above the first insulating film, the second insulating film made of a material different from that of the first insulating film; etching back the first insulating film to such a depth as to reach an upper surface of the buried insulating film, using the second insulating film as a mask, and recessing the buried insulating film exposed to the sidewall portion of the trench; forming a semiconductor layer by epitaxial growth in a gap created by the recessed buried insulating film; and removing the first insulating film and the second insulating film and forming a trench capacitor in the trench.

According to still another aspect of the present invention, there is provided a method of manufacturing a semiconductor device, comprising: forming a trench in an SOI substrate, the trench extending from a major surface of the SOI substrate and passing through a buried insulating film; forming a first insulating film in the trench, the first insulating film with a depth to reach an upper surface of the buried insulating film; forming a second insulating film in a sidewall portion of the trench above the first insulating film, the second insulating film made of a material different from that of the first insulating film; etching back the first insulating film to such a depth as to reach an upper surface of the buried

insulating film, using the second insulating film as  
a mask, and recessing the buried insulating film  
exposed to the sidewall portion of the trench;  
depositing a polysilicon layer on a major surface of  
the SOI substrate and in the trench; etching back the  
polysilicon layer by performing anisotropy etching to  
cause the polysilicon layer to remain in a gap created  
by the recessed buried insulating film in the trench;  
and removing the first insulating film and the second  
insulating film and forming a trench capacitor in  
the trench.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a cross-sectional view schematically  
showing a memory cell formed when a DRAM having  
a memory cell with a trench capacitor structure is  
manufactured by an SOI technique, for illustrating  
a conventional semiconductor device and a method of  
manufacturing the same;

FIG. 2 is a cross-sectional view showing  
a semiconductor device to which an SOC technique for  
combining a DRAM device and a logic device on an SOI  
substrate is applied, for illustrating a semiconductor  
device and a method of manufacturing the same according  
to an embodiment of the present invention; and

FIGS. 3A to 3E are cross-sectional views  
illustrating, in order, manufacturing processes of the  
semiconductor device DRAM array area shown in FIG. 2.

# DETAILED DESCRIPTION OF THE INVENTION

FIG. 2 is a cross-sectional view showing a part of a semiconductor device to which an SOC technique for combining a DRAM device and a logic device on an SOI substrate is applied. Specifically, FIG. 2 illustrates a semiconductor device and a method of manufacturing the same according to an embodiment of the present invention.

As shown in FIG. 2, the semiconductor device has a DRAM array area DA and a logic circuit area LA. A DRAM memory cell and a logic circuit are integrally formed in an SOI substrate 21. In the SOI substrate 21, an oxide film as a buried insulating film (BOX (Buried Oxide) film) 21-3 is formed between a first semiconductor region (substrate) 21-1 at a plate side and a second semiconductor region (P-well region) 21-2 at an element region side.

A trench (deep trench) 22 is formed in the DRAM array area DA of the SOI substrate 21. The trench 22 is of a depth to reach the substrate 21-1, extending from the P-well region 21-2 and passing through the BOX film 21-3, for example, 6  $\mu\text{m}$  to 8  $\mu\text{m}$ . A cell capacitor (trench capacitor) 23 that forms the DRAM memory cell is provided within the trench 22. A conductive material for electrically connecting the substrate 21-1 and the P-well region 21-2, for example, a silicon layer or a polysilicon layer (conductive

layer) 24, is formed between a sidewall portion of the trench 22 and the BOX film 21-3.

An element isolation region 25 of an STI (Shallow Trench Isolation) structure is formed in an upper  
5 portion of the trench 22, thus element isolation is obtained. A source region ( $N^-$  type diffusion layer) 27 of a cell transistor 26 is connected to one electrode of the cell capacitor 23. The cell transistor 26 and the cell capacitor 23 form the DRAM memory cell.  
10 Silicide layers, for example, cobalt silicide layers 29s, 28s are formed respectively on a gate electrode ( $N^+$  type polysilicon layer) 29 and a drain region ( $N^+$  type diffusion layer) 28 of the cell transistor 26, by a Salicide (self aligned silicide) technique.  
15 The gate electrode 29 serves as a word line. An SiN layer 30 is provided in a region between the adjacent gate electrodes of the cell transistor. The cobalt silicide layer 29s and the SiN layer 30 are covered with a plasma SiN layer 31. An interlayer insulating  
20 film 32 made of BPSG, etc., is formed on the SiN layer 31. A bit line 33 made of aluminum, etc., is provided on the interlayer insulating film 32 to extend in a direction crossing the word line. The bit line 33 comes into contact with the cobalt silicide layer 28s  
25 through a contact plug 35 which is made of tungsten, etc., and buried in a via hole 34 formed in the interlayer insulating film 32. Thereby, the drain

region 28 of the cell transistor 26 is connected to the bit line 33.

On the other hand, a transistor 36 for a logic circuit to be formed in the logic circuit area LA is manufactured by the same process as that of the transistor 26 which forms the memory cell, and has a similar structure. That is, cobalt silicide layers 37s, 38s, 39s are formed respectively on a gate electrode 37, a source region 38 and a drain region 39 of the transistor 36, by a Salicide technique. The cobalt silicide layer 37s is covered with the SiN layer 31. The interlayer insulating film 32 is formed on the SiN layer 31. A source electrode 40 and a drain electrode 41 made of aluminum, etc., are formed on the interlayer insulating film 32. The source electrode 40 and the drain electrode 41 come into contact with the cobalt silicide layers 38s, 39s through contact plugs 45, 46 which are made of tungsten, etc., and buried in via holes 42, 43 formed in the interlayer insulating film 32. The source and drain electrodes 40, 41 are electrically connected to the source and drain regions 38, 39, respectively.

According to the above structure, since the P-well region 21-2 and the substrate 21-1 are electrically connected by a conductive material such as silicon or polysilicon, the P-well region 21-2 can be prevented from being in a floating state. Thus, the operation of



the cell transistor can be stabilized.

In FIG. 2, an example to which the Salicide technique is applied in order to enhance the operation speed by reducing sheet resistance of the transistor 36 in the logic circuit area LA is explained. However, the above is not an indispensable structure, and the silicide layer may be omitted.

Next, with reference to FIGS. 3A to 3E, a method of manufacturing a vicinity region of the cell capacitor (trench capacitor) 23 in the DRAM array area DA having the structure as above will be explained. First, an SOI substrate 21 is formed using a semiconductor substrate bonding technique, for example. Specifically, as shown in FIG. 3A, two semiconductor substrates (silicon substrates) 21A, 21B having oxide films 20A, 20B formed on one surface thereof are prepared. After bonding the oxide films 20A, 20B formation surface sides of the substrates to each other, heat treatment is performed to combine the two semiconductor substrates 21A and 21B. Thereby, a composite substrate is formed. After that, one surface side of the bonded substrate, which is to be the P-well region 21-2, is ground and polished away to the point indicated by a broken line to have a thin thickness. Thereby, the SOI substrate 21 is formed comprising the semiconductor substrate 21A as a first semiconductor region (substrate) 21-1, the remaining

region of the semiconductor substrate 21B as a second semiconductor region (P-well region) 21-2, and the oxide films 20A, 20B as a BOX film 21-3.

5       Next, as shown in FIG. 3B, using an anisotropy etching technique such as RIE, etc., a trench 22 for a cell capacitor with a depth of 6  $\mu\text{m}$  to 8  $\mu\text{m}$  to reach the substrate 21-1, extending from the P-well region 21-2 and passing through the BOX film 21-3, is formed.

10       An insulating film (e.g. silicon oxide film) 50 is then deposited on the entire surface. Afterwards, the insulating film 50 is removed by wet etching to the depth of the upper portion of the BOX film 21-3, as shown in FIG. 3C. Thereby, the bottom portion of the trench 22 is buried by the insulating film 50.

15       An insulating film (e.g. NO film, SiN) 51 different from the insulating film 50 is then deposited. Only the part of the film 51 on the insulating film 50 is removed by RIE.

20       After that, the insulating film 50 is removed by etching to the lower portion of the BOX film 21-3. At this time, the BOX film 21-3 is also recessed by etching, as shown in FIG. 3D.

25       Next, as shown in FIG. 3E, a silicon layer 24 is formed by epitaxial growth to bury a gap created by the recessed BOX film. At this time, since all portions except the gap portion are insulators, silicon is formed only in the gap portion. Alternatively,

a polysilicon layer may be deposited within the trench 22 and anisotropy etching such as RIE, etc., may be performed, thereby providing polysilicon only in the gap created by the recessed BOX film 21-3.

5           The insulating films 50 and 51 remaining within the trench 22 are then removed, and a cell capacitor 23 is formed by a well-known manufacturing process. Semiconductor devices such as a transistor, etc., are formed on the areas except the capacitor 23, using  
10           the manufacturing process common to DRAM array area DA and logic circuit area LA formation. That is, a device structure comprising a DRAM array area and a logic circuit area (or DRAM peripheral circuit area) can be achieved by performing a well-known STI process  
15           (formation of the element isolation region 25), transistor formation process, wiring formation process, etc.

          According to the manufacturing method as described above, if the cell capacitor 23 is formed in the SOI  
20           substrate 21, the P-well region 21-2 and the substrate 21-1 can be electrically connected to each other by the epitaxial layer 24 (or polysilicon layer). Thus, the P-well region 21-2 on which a device is formed can be prevented from being in a floating state.  
25           A stable operation of the cell transistor 26 can thus be obtained.

          The manufacturing process of the DRAM array area

DA and the logic circuit area LA can be simplified if the common structural portions are formed by the same manufacturing process. However, if each of the DRAM portion and logic circuit portion is desired to be  
5 provided with optimum device characteristics, both may be formed by separate processes.

As described above, according to one aspect of this invention, a semiconductor device and a method of manufacturing the same can be obtained which can  
10 prevent a semiconductor region, on which a device is formed, from being in a floating state, if a trench capacitor is formed in an SOI substrate, and thus can stabilize an operation of the device.

Additional advantages and modifications will  
15 readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the  
20 spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.